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STUDY OF ROCK PROPERTIES OF THE COAL SEAMS AND ROCK STRATA OF THE UNDERGROUND SILKSTONE PROJECT AT COAL VALLEY OF LUSCAR LTD.

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by

B. Das[1] and K.L. Kar[2]

SUMMARY

The rock properties at the Underground Silkstone Mine at Coal Valley of Luscar Ltd. have been studied using three portable testing devices, i.e. Robertson point load tester, Schmidt rebound hammer and Protodyakonov dynamic impact strength device. The rock strata appear to belong to three distinct zones, i.e. weathered, transition and stable. Lithologically the rocks are classified into the following broad groups: sandstone, siltstone, mudstone/shale, coal and mixed type. Point load strength tests have been found to be suitable for the unweathered zone. Protodyakonov test was suitable only for coal. The evaluation of rock properties in the weathered zone is useful in predicting deterioration of strength properties due to weathering as may be expected in subsided areas.

As sufficient amount of suitable samples for test were not available, it would be premature to draw final conclusions. However, based on the present results it is possible to draw some conclusions on the rock properties and their variation due to weathering and the relative suitability of the portable testing devices. The strength properties, as expected, are low in the weathered zone and increase in the other zones attaining maximum or normal values in the stable zone.

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ÉTUDE DES PROPRIÉTÉS DES ROCHES PROVENANT DES FILONS HOUILLERS ET DES COUCHES DE ROCHES DU PROJET D'EXPLOITATION DE LA MINE SOUTERRAINE SILKSTONE DE LA LUSCAR LTD. À COAL VALLEY

par

B. Das[1] et K.L. Kar[2]

RÉSUMÉ

On a étudié les propriétés des roches de la mine souterraine Silkstone de la Luscar Ltd. à Coal Valley au moyen de trois dispositifs d'essais portatifs, i.e., l'appareil Robertson pour les essais de charge concentrée, le marteau Schmidt et le dispositif d'essai dynamique de Protodyakonov pour mesurer la résistance au choc. Les couches de roches semblent provenir de trois zones distinctes; zone d'altération, zone de transition et zone stable. La lithologie classe ces roches dans les grands groupes suivants: les grès, les limons, les shistes argileux, les argiles, les charbons et les mélanges. On a déterminé que les essais de charge concentrée conviennent aux zones altérées. L'essai selon la méthode de Protodyakonov convenait seulement aux filons houillers. La détermination des propriétés des roches de la zone altérée s'avère utile pour la prévision de la détérioration des propriétés de résistance de la roche attribuable à l'érosion qui se produit généralement dans les régions affaissées.

En raison d'un manque d'échantillons appropriés lors des essais, il serait présomptueux de tirer des conclusions finales. Cependant, les résultats actuels nous permettent d'arriver à certaines conclusions relatives aux propriétés des roches et aux variations qu'elles subissent par l'érosion et à déterminer jusqu'à quel point les dispositifs d'essais portatifs sont appropriés. Tel que prévu, les caractéristiques de résistance sont basses dans les zones altérées et s'accroissent dans les autres zones pour atteindre des valeurs maximales ou normales dans la zone stable.

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INTRODUCTION

Coal mining around the Coal Valley area started in the beginning of this century. In 1911, production commenced from the Silkstone (Wee) seam near Lovett. The mine was abandoned in 1920 (Rogan, M. and Shewchuk, G., 1979). Another mine was opened in 1923 to mine coal from Wee seam but was closed in 1925.

In the modern era, Luscar Ltd. of Edmonton has initiated the work of mining coal from the Silkstone seam by underground method. Initially, the idea was to mine coal from the Silkstone seam starting from the highwall by punch mining. To make this project most effective Luscar Ltd. in February 1980 invited CANMET to participate in this project. Eventually, the idea changed and Luscar Ltd. decided to develop an underground mine from the high wall. The operation was planned to be an experimental one using room and pillar method to start with. It was agreed that CANMET's principal activities at the initial phase would be rock mechanics/geotechnical investigations and study of methane potentials. Others area, such as spontaneous heating of coal and surface subsidence would likely be initiated by CANMET in the near future.

The experimental mine known as Silkstone Underground Project (Mine) was started in the autumn of 1982. CANMET has completed the main part of the methane desorption study on drill core samples (Das, B. et al., 1982). In rock mechanics/geotechnical investigations, CANMET has advised Luscar Ltd. in various matters, helped them in some evaluation and has carried out some work on rock properties using three different portable testing equipments. CANMET has also installed a few load cells in the underground roadways for evaluating support load. This particular report, however, deals with the preliminary study of rock properties using the portable testing equipments. The final report will be ready after carrying out the full series of tests.

LOCATION AND GEOLOGICAL CHARACTERISTICS

The Coal Valley area is located in the outer foothills belt of the Rocky Mountain Eastern Slopes, 96 km southwest of Edson, Alberta, (Fig. 1). There is some controversy as to the precise age of the rock measures in this

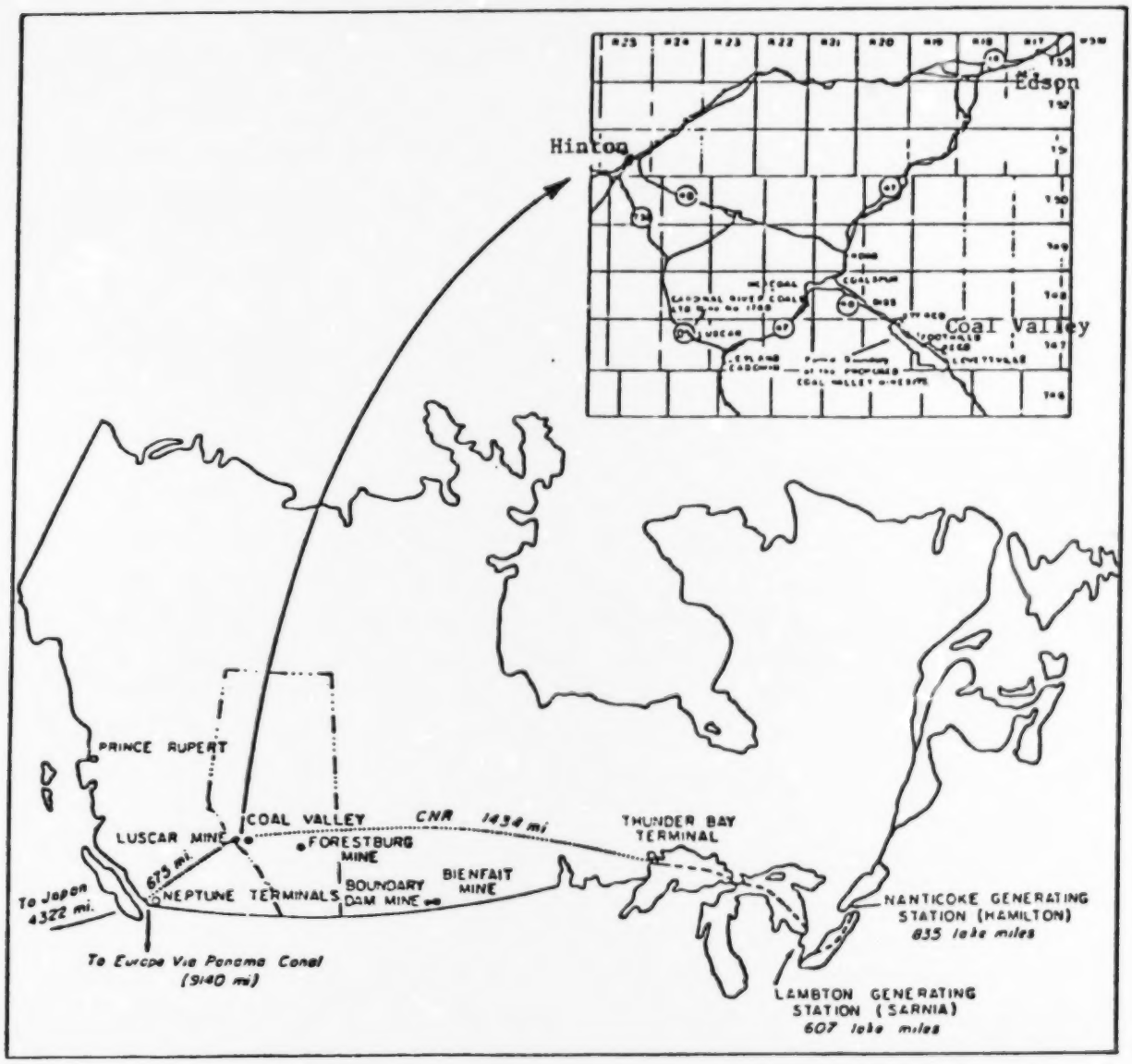


Fig. 1 - Location map of the Coal Valley property of Luscar Ltd.

area. It is described as of Upper Cretaceous age (Allan, J.A. and Rutherford, R.L., 1924), of Paleocene (Early Tertiary) age (Bell, W.A., 1949) and of Latest Cretaceous age (Eliuk, L.S., 1969). There are four principal coal seams/zones in this area - Val D'Or, Arbour, Silkstone and Mynheer in descending order. It has been concluded that Val D'Or and Arbour seams are of Paskapoo (Paleocene age) while Silkstone and Mynheer Seams are of Maestrichtian (Latest Cretaceous age)(Rogan, M. and Shewchuk, G., 1979). The area is disturbed by tectonics with some major faults existing in this area. Some more details of the coal seams in the proposed mining area as described by Rogan, M., 1982 are provided below:

The proposed underground mining area in Coal Valley lies within a fault enclosed synclinal plate identified as the Lovett River Syncline. Four major coal seams, comprising the entire coal bearing measures of the Saunders Formation (also referred to as the Coalspur Beds) occur within the boundaries of the Lovett River Syncline. They are identified, from youngest to oldest, as the Val D'Or, Arbour, Silkstone (Wee Seam) and Mynheer.

At the present time, it is proposed to mine only the Silkstone seam by underground method. The Val D'Or, which overlies the Silkstone by approximately 165 m, occurs at shallow depth and is largely recoverable by surface mining. The Arbour seam underlying the Val D'Or is a zone of highly interbedded mudstone, bentonite and coal beds. The high proportion of partings to coal makes the Arbour seam difficult to mine by either surface or underground methods. At the present time it is not considered a source of recoverable coal. The Mynheer seam, which underlies the Silkstone by approximately 60 m, is considered mineable by underground methods; however, conditions associated with its extraction are still being investigated.

The Silkstone coal zone consists of two coal seams, the Wee and the Bourne, separated by about 8-9 m of silty-mudstone. The upper seam (Wee) averages about 3 m thick which includes a major mudstone parting (usually less than 0.3 m thick) near the middle of the seam. The Bourne seam, underlying the Wee, is a thin, but consistent coal seam occurring throughout the proposed mining area. The coal seam, which is free of partings, averages 0.75 m thick. At the present time this seam is not being considered for mining. The Wee seam outcrops on the north limb of the syncline, south of the Lovett River. Superimposed on the north limb are minor parasitic folds which trend northeast along strike. The effect of this minor

fold belt is to locally thicken and thin the coal seam and increase the area of shallow coal deposits. Depth of cover for the seam rises rapidly toward the south as a result of local dip and abrupt rise in surface topography. A maximum depth of 304.8 m is expected for the coals mined near the bottom of the synclinal trough.

The coal from the Silkstone seam is high volatile bituminous in rank. It can be concluded from the study carried out by CANMET (Das, B. et al., 1982) that the coal seam will be generally gassy but not to any extreme limit.

UNDERGROUND SILKSTONE MINE

The Underground Silkstone project (also known as Underground Silkstone Mine or Silkstone Mine) is an underground coal operation to mine coal from the Wee seam (also known as Silkstone seam or zone) at Coal Valley of Luscar Ltd. The mine development work was initiated in the autumn of 1982. The main entries to the mine have been driven in the seam from the highwall in the Pit No. 33 (Fig. 2 and Fig. 3). The roadways are driven in the Wee seam of the Silkstone seam zone which consists of 2 seams as described before. The Wee seam is the only economically mineable section at the moment.

At the experimental stage, the mine is being developed by room and pillar method and it is expected that the feasibility of other mining methods will also be studied for long-term planning. Athough, only the Wee seam is considered for underground mining at this stage, it is expected that the Mynheer seam, which is about 80-90 m below the Silkstone seam will be eventually considered. Therefore it would be necessary to investigate problems related to multiple seam mining including that of the percolation of rain water in the mined out area of the Silkstone seam through subsidence cracks at shallow depths.

Silkstone Mine is the first modern underground coal mine in the Foothills. The Foothills coal fields are different from those in the plains or in the Mountains in respect of coal rank and type, geotechnical properties of the coal and other rocks, gas content, proneness to spontaneous heating, tectonics, etc. Geologically the coal seams are much younger than the

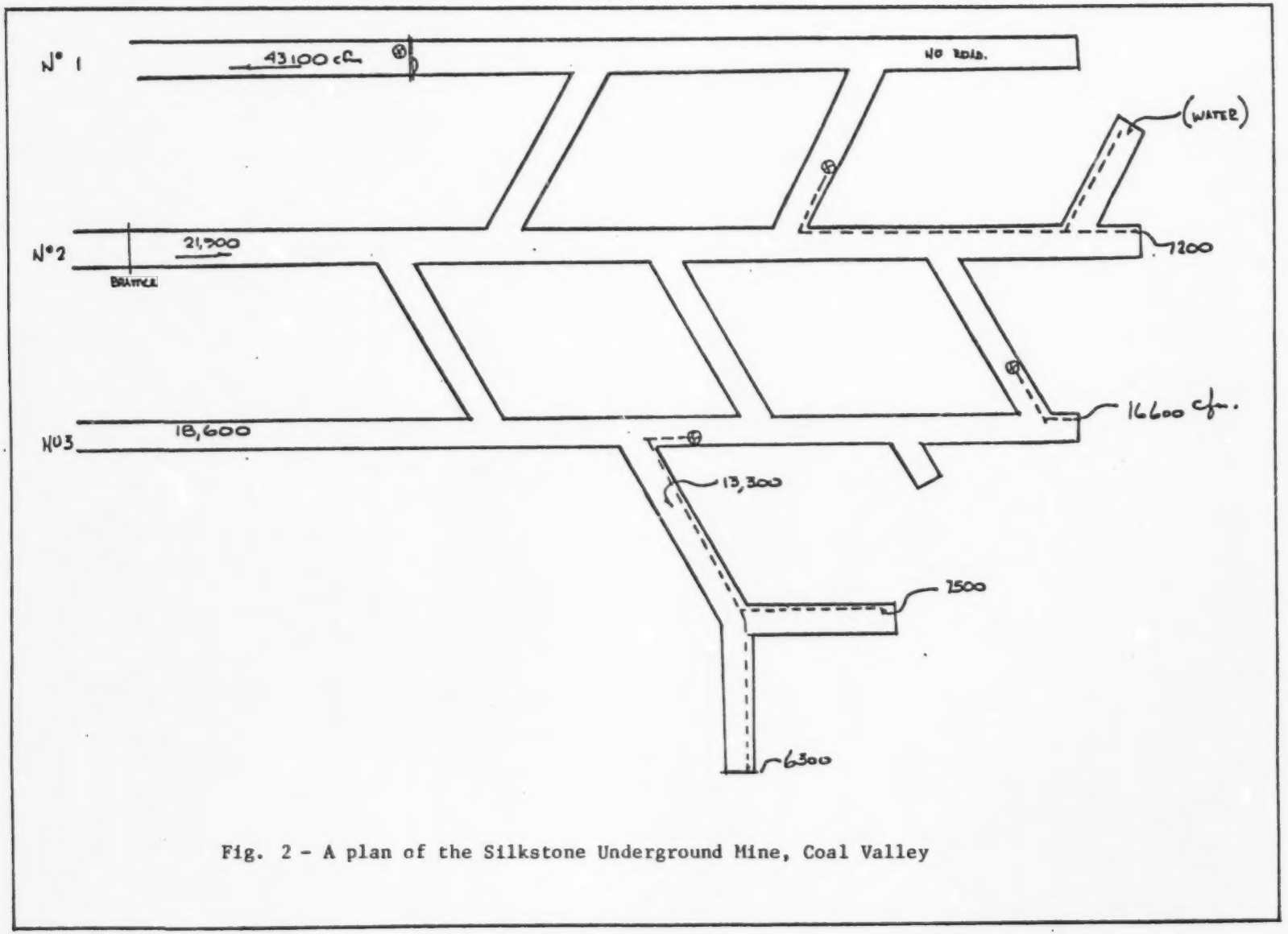


Fig. 2 - A plan of the Silkstone Underground Mine, Coal Valley

mountains coals and often younger than the plains coals but more mature than the latter.

The depth of mining in the planned mine would range from the outcrop to just over 300 m but the test mine will be developed to a maximum depth of about 135 m. The coal is expected to be highly liable to spontaneous heating. The coal seams can be considered as gassy but in the test mine it is not likely to be critical. This has been confirmed by methane desorption study carried by CANMET in the field except for the deeper part of the property (Das, B. et al., 1982).

GENERAL GEOTECHNICAL CHARACTERISTICS OF THE UNDERGROUND SILKSTONE MINE

Geologically, the Silkstone seam is in the Foothills region. The rock strata are mature and consolidated. They are more affected tectonically than the beds in the Plains but to a much lesser extent than those in the Mountains region. These coals are generally of high volatile bituminous in rank (thermal coal) and are hard and elastic. They are much less brittle than the Mountain coals but more than those in the Plains.

The floor rock is composed of a consistently fine grained medium to dark grey, medium hard mudstone with occasional interlayered sandstone and siltsone beds. The immediate roof generally consists of fine to medium grained, light grey salt and pepper sandstone ranging from 1.52 to 6.06 m thick and a mudstone layer 6.06 to 7.58 m thick. The remaining strata to surface is a thick massive sandstone (Rogan, M., 1980). In practice the immediate roof changes from sandstone to siltstone to mudstone in different parts of the property. Any flow and accumulation of water is likely to cause deterioration of the mudstone floor. It is therefore important to keep the floor free of water.

There is a band of bentonitic clay in the coal which may affect the geotechnical behaviour of the coal pillars specially due to swelling in the presence of water.

In view of the fact that the test mine will be developed to a maximum depth of about 135 m this will result in the following consequences:

- During depillaring subsidence cracks are likely to reach the surface. These cracks may intersect the water table. There can

therefore be drastic increase in water percolation into the mine whether from ground water or from rain water.

- This water inflow can affect the floor mudstone as well as the bentonitic layer affecting drastically their geotechnical properties.
- There may be leakage of air through these subsidence cracks which is undesirable in view of the high proneness of this coal to spontaneous heating.
- Prolong exposure of the coal and rock strata to air and water in and over the mined out areas can worsen their geotechnical properties as noticed in the weathered zone.

Therefore in the test mine these effects should be systematic studied for long range planning.

As mentioned before, from the geotechnical point of view the mine can be divided into three zones: (a) weathered zone, (b) transition zone, (c) stable zone. The spatial extent of the different zones remain to be determined through underground observation, study of the drill cores and through rock properties testing. In the weathered zone there may be the problems of side spalling and rock falling and water percolation which can affect the mudstone floor. These problems are expected to diminish in the transition zone and will be less important in the stable zone.

A systematic evaluation of the rock properties in the different zones may help in:

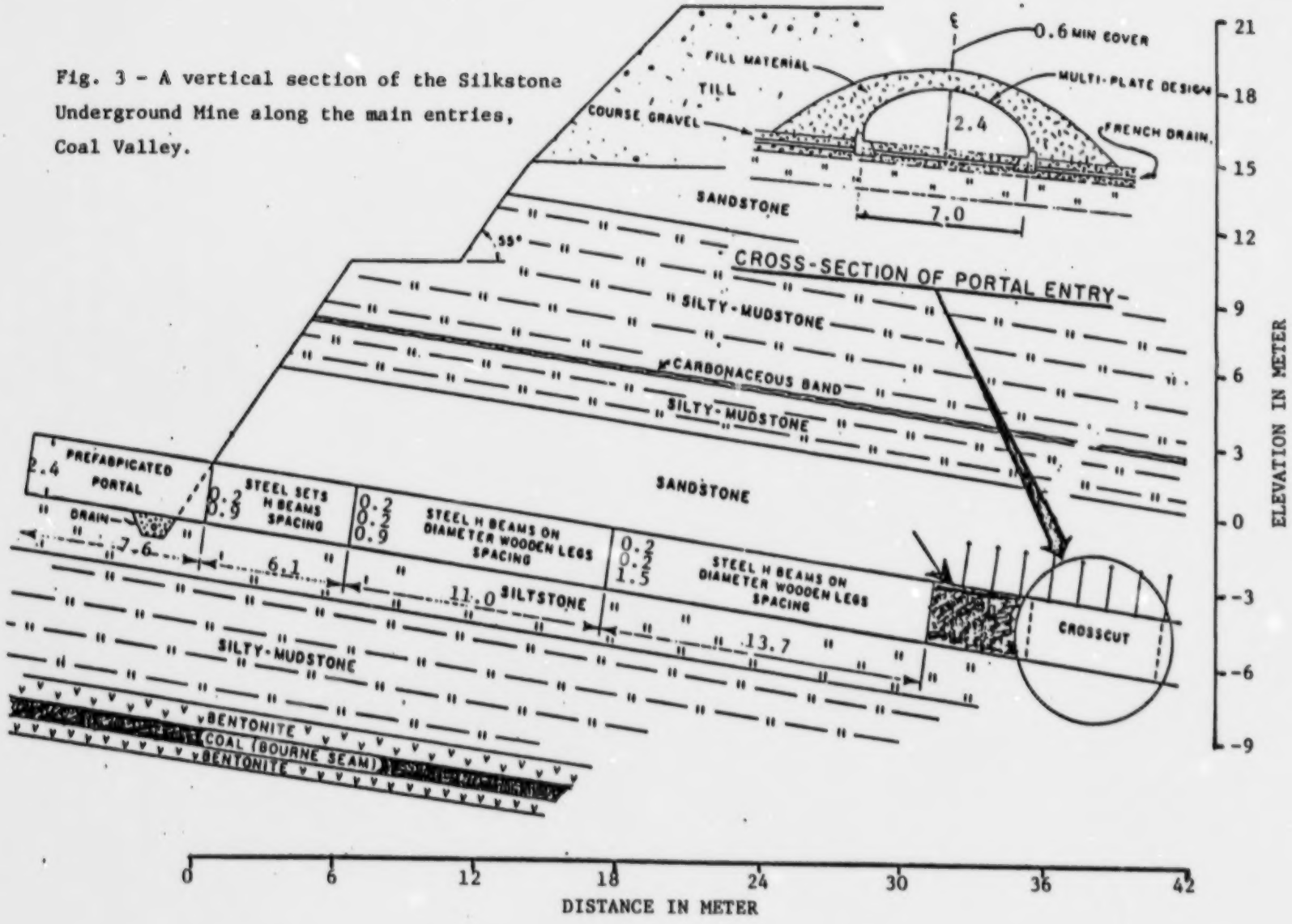
- Demarcating the different zones as stated above.
- Designing mine layout and support systems for various zones.
- Predicting the properties of rocks in the subsided areas due to weathering for predicting subsidence.

AN OUTLINE OF THE TEST METHODS

The following tests were performed for evaluating the rock properties:

- Point load strength test using the Robertson Research instrument.
- Rebound strength test using the Schmidt Test Hammer Type NR.

Fig. 3 - A vertical section of the Silkstone Underground Mine along the main entries, Coal Valley.



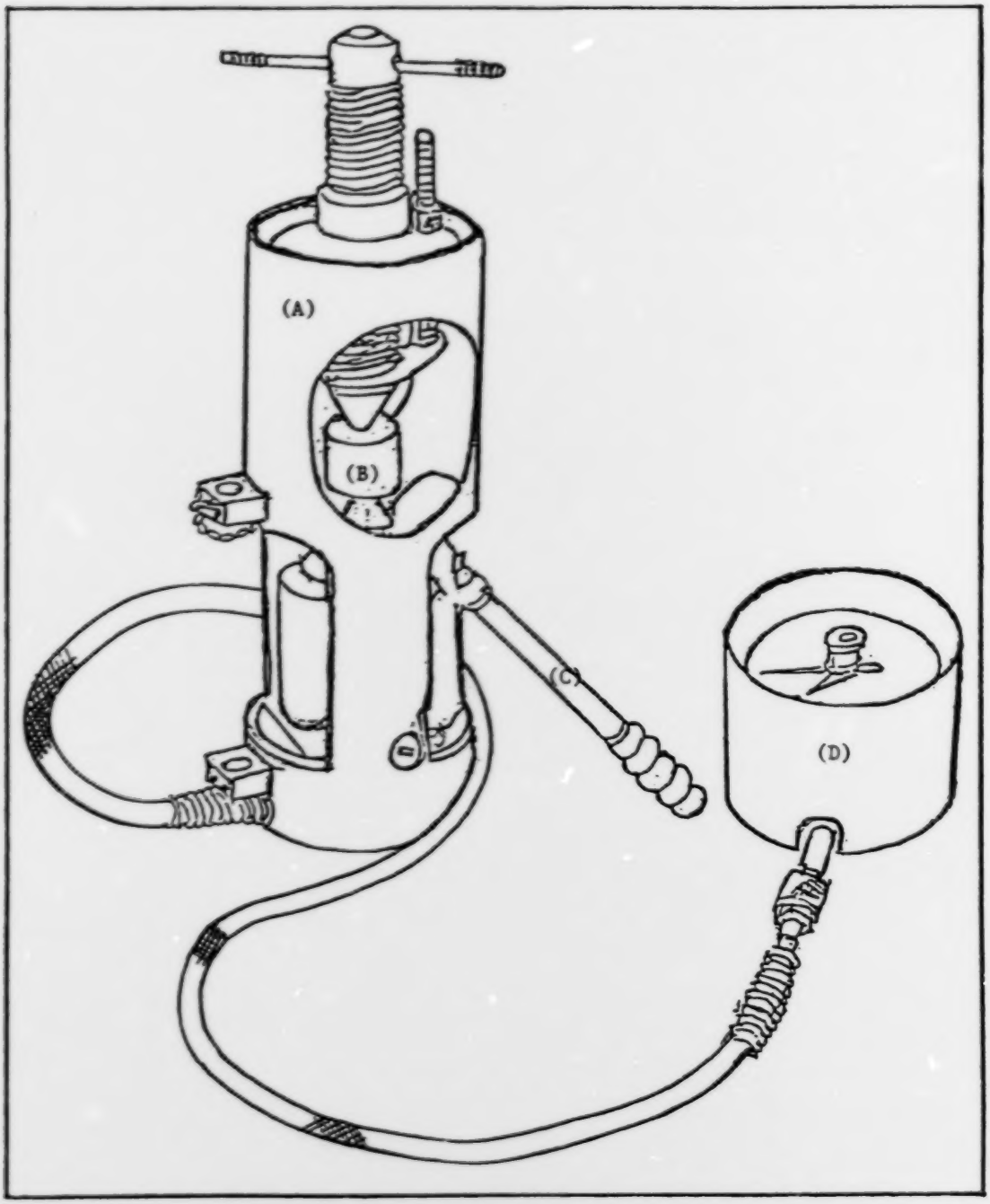


Fig. 4 - View of the point load testing device
(A) main body, (B) sample between the platens
(C) operating handle, (C) pressure indicator.

- Protodyakonov dyanmic impact test using the Protodyakonov device.

The tests were performed in situ, on drill core samples and on samples collected from the highwalls and from the underground workings at the Silkstone Mine.

Although the study covers all the above three tests, the results of the point load and rebound strength tests are mainly provided in this report.

POINT LOAD STRENGTH TEST

Historically, the point load strength tests were developed in Russia (Protodyakonov, M.M., 1960, 1961). The idea behind these tests was to find a suitable test method for irregular samples. Protodyaknov used conical platens and nearly egg-shaped specimens with ratio of longest to shortest diameter of about 1.5 to 1 and volume of about 100 cm^3. Protodyakonov calculated some strength index by dividing the breaking load by 2/3.

International Society of Rock Mechanics has recommended the use of the point load strength index for rock classification purpose and for determining uniaxial compressive strength (IRSM, 1972). This testing method has been utilized by other authors for studying rock properties and rock classification (Broch, E. and Franklin, J.A., 1972; Carter, P.G. and Sneddon, M., 1977; Bieniawski, Z.T., 1975; Reichmuth, D.R., 1968; Haramy, K.Y. et. al., 1982; Pells, P.J.N., 1975).

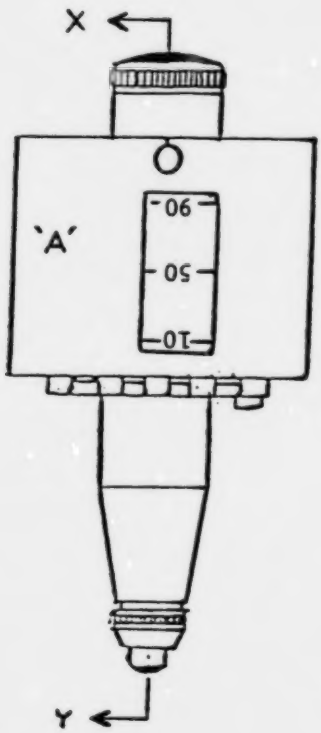
The point load strength index is expressed as follows:

$$I_s = \frac{P}{D^2}$$

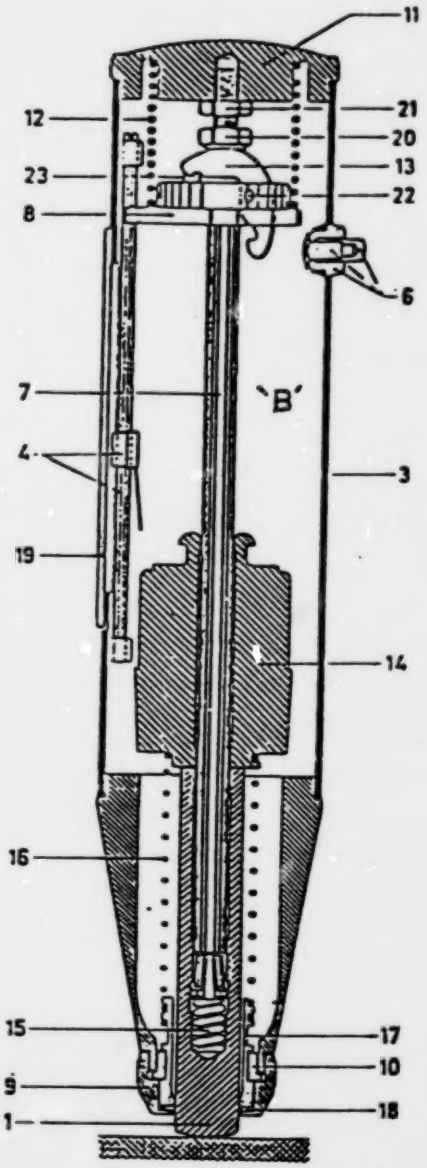
where I_s = Point load strength index
P = Applied force at failure
D = Platen separation.

The point load strength index being a new parameter it was necessary to standardize it and to establish some sort of correlation with some known parameter to facilitate its use. The index was standarized for D = 50 mm (known as $I_s(50)$) as follows:

$$I_s = 140\ P.D^{-1.5}(MPa)$$



1 Impact plunger
3 Housing compl.
4 Rider with guide rod
6 Pushbutton compl.
7 Hammer guide bar
8 Disk
9 Cap
10 Two-part ring
11 Rear cover
12 Compression spring
13 Pawl
14 Hammer mass
15 Retaining spring
16 Impact spring
17 Guide sleeve
18 Felt washer
19 Plexiglass window
scale printed on window
20 Trip screw
21 Lock nut
22 Pin
23 Pawl spring



CROSS-SECTION XY

Fig. 5 - Schmidt Hammer for rebound test

where P = Load at failure (KN)

D = Platen separation (mm)

This has been found to be a standard index with an approximate conversion: Uniaxial Compressive Strength = 24 x $I_s(50)$(Broch, E. and Franklin, J.A., 1972). However, the present study indicates that this conversion ratio may be drastically different for soft and hard rocks. It is therefore recommended to establish this correlation for the Canadian coal measure rocks.

The point load tester is a portable device and can be used both in the field and in the laboratory (Fig. 4).

REBOUND STRENGTH TEST

The rebound hammer test was originally introduced to determine the strength of concrete (Kolek, J., 1958). But this method was found useful also for the coal measure rocks (Hucka, V., 1965; Carter, P.G. and Sneddon, M., 1977). The fraction of elastic rebound energy to the total energy of impact expressed as the height of rebound is an index of strength (Das, B., 1973). In spite of some limitation this rebound height is correlated roughly with the uniaxial compressive strength of rocks. The correlation coefficient or the correlation curve for each rock type must be established.

It is a very simple and cheap method and the test can be performed both in the laboratory and in situ. A large number of test sites can be covered for this test during the course of a day. The equipment is also very simple and not very expensive (Fig. 5).

PROTODYAKONOV DYNAMIC IMPACT TEST

This is a simple method of determining strength of moderately hard but brittle rocks (e.g. bituminous coal) by shattering the specimens by a fallen weight. This test was developed by Protodyakonov, M.M. in U.S.S.R. for determining the strength of irregular samples (Protodyakonov, M.M., 1962). Each sample of size about 20-27 mm is placed in a cylinder of 76 mm internal diameter and is shattered with a 2.378 kg weight dropped from a height of 60.8 cm along the cylinder (Fig. 6). The number of impact (n) to which each test specimen is subjected to varies from 3-5 for coal. This procedure is repeated on 5 samples and the disintegrated product is passed

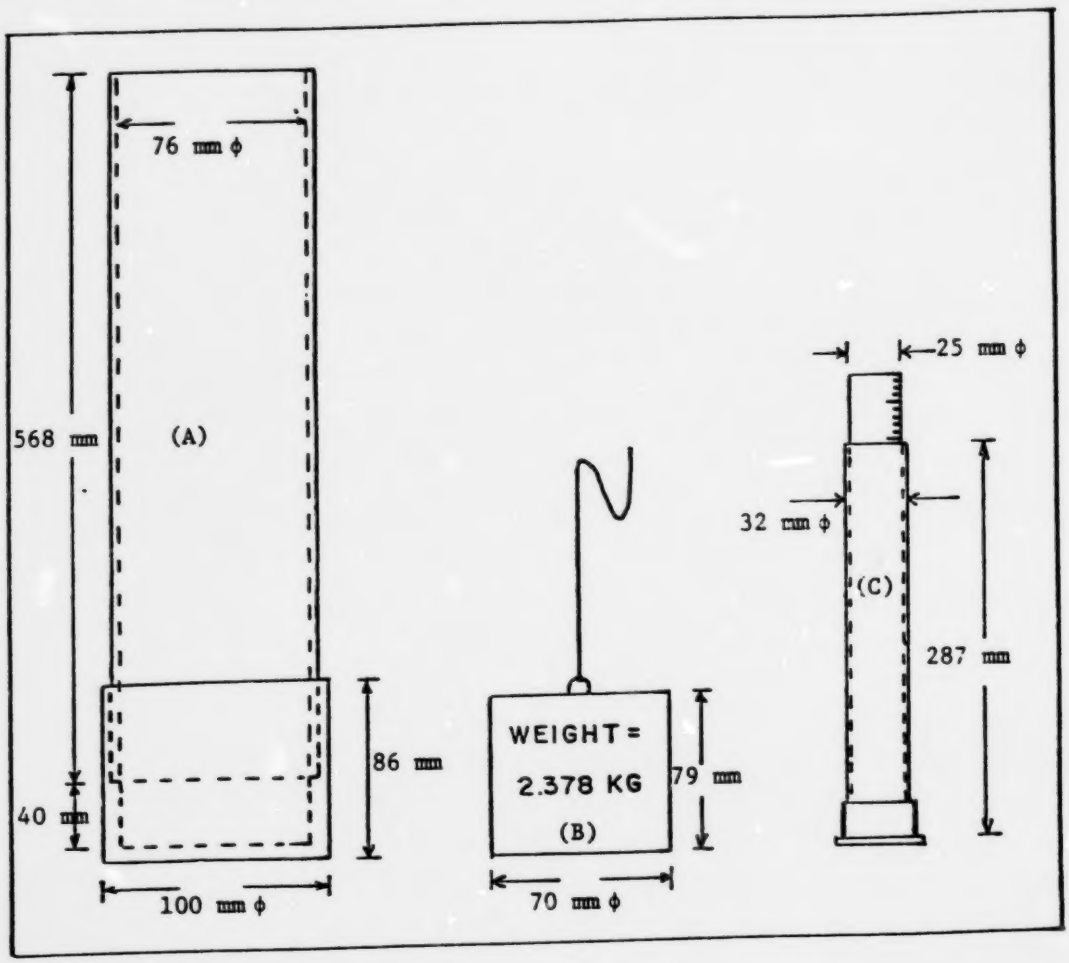


Fig. 6 - The Protodyakonov dynamic impact testing set (A) cylinder, (B) drop weight (C) cylinder for measuring the volume of the fines.

through a 0.5 mm sieve. The minus 0.5 mm product is poured into a tube of 23 mm internal diameter and the height of this product (ℓ) is noted. The strength of the rock is found to be an inverse function of the volume of the fines and is determined using the following empirical equation:

$$\sigma_d = 1060\ \ell_3^{-1.38}$$

where σ_d = Dynamic impact strength (MPa)

ℓ_3 = Height of the fines after 3 impacts (mm).

Several modified forms of this test have been developed by various authors (Evans, I. and Pomeroy, C.D., 1966; Brook, N., 1970; Selim, A.A. and Bruce, W.E., 1970).

TEST PARTICULARS AND RESULTS

TEST PARTICULARS

As stated before, the rock properties were determined mainly using three different testing devices: Robertson point load strength tester, Schmidt test hammer and Protodyakonov dynamic impact testing device. Some tests for evaluating uniaxial compressive strength and tensile strength were also carried out on the newly installed compression testing machine at the Calgary Coal Research Laboratory but they were aimed at verifying the performance of the machine rather than determining for rock properties. Rebound tests using Schmidt hammer were carried out mainly in situ, although some were performed in the laboratory on the large rock samples collected from the mine. Point load tests were made both in the field on the freshly cut rock samples and in the laboratory on the samples collected from the mine. Protodyakonov tests were made only on coal samples in the laboratory.

As described before, from the geotechnical point of view there exists three distinct zones in the Silkstone Mine, e.g. weathered zone, transition zone and the stable zone. It was decided therefore to collect

Table 1 - The results of the point load strength tests on samples from the Silkstone Mine, Coal Valley

Rock type	Number of samples	Point Load Strength Index - $I_s(50)$ (MPa)									Remarks
		Weathered zone			Transition zone			Stable zone			
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
Sandstone		0.02	1.70	0.36	0.38	2.41	2.04	4.30	10.80	7.92	Not recommended for weathered and wet samples
Siltstone		0.05	0.34	0.19	1.10	3.50	1.92	1.36	13.57	5.24	Ditto
Mudstone/ Shale		0.03 crumbles when wet	1.42	0.14	-	-	-	0.78	8.88	3.78	Ditto
Coal		crumbles			0.08	1.78	0.97	1.83	6.27	2.79	Ditto

Table 2 - The results of Schmidt Hammer rebound tests at the Silkstone Underground Mine, Coal Valley

Rock type	Number of points tested	Schmidt Hammer Rebound Number									Remarks
		Weathered zone			Transition zone			Stable zone			
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
Sandstone		2.7	39.3	26.4	20.3	43.5	38.4	20.4	50.3	38.2	
Siltstone		3.8	19.2	14.3	11.8	33.2	26.4	15.7	37.3	28.7	
Mudstone/ Shale		-	-	-	-	-	-	-	-	-	
Coal		Negligible			7.3	17.2	13.1	-	-	-	

Table 3 - The results of the Protodyakonov dynamic impact tests on samples from the Underground Silkstone Mine, Coal Valley

Rock type	Number of samples	Protodyakonov Dynamic Impact Strength (MPa)									Remarks
		Weathered zone			Transition zone			Stable zone			
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
Sandstone		-	-	-	-	-	-	-	-	-	Not suitable
Siltstone		-	-	-	-	-	-	-	-	-	Not suitable
Mudstone/ Shale		-	-	-	-	-	-	-	-	-	Not suitable
Coal	27	3.2	7.8	5.4	16.1	49.6	27.6	37.6	63.8	43.2	The results may be different if a different correlation formula is used

samples from the above three zones. The samples from the open pit highwalls and from the underground roadways upto a depth of about 30 m (conditional) belong to the weathered zone. These samples were easily obtainable. The samples from the assumed transition zone were obtained from the deeper part of the roadways developed in the Silkstone Mine as well as from drill cores, but those from the stable zone were mainly obtained from exploration drilling at the deeper parts of the seam.

The samples from the various zones were divided into four broad rock types or lithological groups (sandstone, siltstone, mudstone or shale and coal) for the purpose of this study. A summary of the test results is presented in Tables 1, 2 and 3.

TEST RESULTS

Point Load Strength Index

The results of the point load strength tests are presented in Table 1. In the weathered zone some very low results were obtained for sandstone siltstone and mudstone (dry) but the samples of coal and wet mudstone simply crumbled without giving any tangible reading. This also occasionally happened for sandstone and siltstone. A maximum value of 1.70 MPa was obtained for sandstone in this zone and for siltstone this was 0.34 MPa.

In the transition and stable zones however, the point load strength tester seems to be quite useful. The mean value in the transition zone for different rock types are as follows: sandstone - 2.04 MPa; siltstone -1.92 MPa; mudstone - (no sample) and coal - 0.97 MPa. The corresponding values in the stable zone are: 7.92, 5.24, 3.78 and 2.79 MPa respectively.

Schmidt Hammer Rebound Number

These results are provided in Table 2. Schmidt hammer rebound number also indicates a certain improvement in the strength characteristics from the weathered zone to tansition zone to the stable zone. The lowest value in the weathered zone and the highest value in the stable zone for sandstone are respectively 2.7 and 50.3. The corresponding values for siltstone are 3.8 and 37.3 respectively. No suitable test points were available for mudstone. Although, they were available for coal in the weathered and in the transition zones, the values in the former zone are negligible whereas in

the latter zone the minimum, maximum and the mean values as recorded are 7.3, 17.3 and 13.1 respectively.

Protodyakonov Dynamic Impact Strength

The results of Protodyakonov dynamic impact tests have been found to be suitable only for coal although more study is recommended for this. Other rocks are either too ductile or too strong for this test. The mean values of the Protodyakonov dynamic impact strength in the weathered, transition and stable zones have been found to be 5.4, 27.6 and 43.2 MPa respectively. These values are only provisional as different correlation formula may alter the values. Further study may be made to see the possibility of this test for rocks other than coal.

CONCLUSIONS

Robertson Point load tester has been found to be useful in evaluating the strength properties of the coal and rocks in the Foothills, but not for the weathered rocks as they become too soft to indicate any significant reading in the scale. However, if a magnified scale is used, it is expected the point load test will be effective also for soft rocks.

Although some tests have been made for determining uniaxial compressive strength as well as tensile strength of rocks, no attempt is made here to correlate these with the point load strength, rebound hammer number and Protodyakonov dynamic impact strength, because of the insufficient number of data of the first two properties. The study will be continued in this respect.

The division of the rock strata into three geotechnically distinct zones according to the depth of the coal seam at the Silkstone Mine is very useful. This will be quite helpful in designing mine layout and support system. However, it will be necessary to carry out further study for more precise demarcation of these zones.

The evaluation of rock properties in the weathered zone throws some light on the extent of deterioration of rock properties that may be expected in the subsided areas when mining progresses. This is specially important for the Silkstone Mine, a substantial part of which will be at a shallow

depth having a large amount of ground water.

Protodyakonov test in its present form was found to be suitable only for coal. It is worth investigating for any possible modification to render it suitable for hard but brittle rock. The very principle of this method makes the ductile rocks unsuitable for this test.

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